Colliding Without Relaxing: The Suppression of Collisional Dephasing with Strong Optical Fields

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Recently, considerable interest has arisen in the effect of relaxation on systems which are being strongly driven by a resonant electromagnetic field [1-6]. While this problem was originally encountered in studies of nuclear magnetic resonance, recent interest was sparked by experiments conducted in solid-state materials [5,6] which indicated that strong driving fields can act to suppress optical relaxation. We have experimentally studied the relaxation of optical coherences (off-diagonal density matrix elements) introduced by gas-phase atomic collisions, and find that it can also be suppressed (at least in part) by a strong driving field [7]. Superficially at least, our results are surprising, because the "strong" driving field employed in our experiment was far too weak to influence the dynamics of the picosecond duration collisions and the phase-randomization they produce. It turns out that our driving field suppresses the relaxation normally introduced by collisionally-induced Doppler shifts (velocity changes) whose effect accrues over the relatively long intervals between collisions. As described elsewhere [8], velocity changes occur in distant, weakly-phase-perturbing collisions.

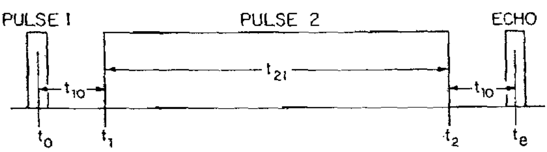

Figure 1. Excitation pulses and echo.

Our modified photon-echo type experiment employed two excitation pulses (see Fig. 1) tuned to resonance with the 555.6 nm $(6s^2)\ ^1S_0$ - $(6s6p)\ ^3P_1$ transition of atomic Yb in a vapor cell. When pulse 2 is sufficiently intense, this excitation scheme produces an echo at the time shown with a duration roughly equal to that of the first pulse. For fixed excitation pulse times, the echo intensity, I_e, decays exponentially with argon perturber gas pressure P, i.e. $I_e = I_0 \exp(-\beta P)$. As shown in Fig. 2 (solid circles), we have measured β as a function of t_{21} while keeping the total interval between pulse 1 and the echo fixed at t_{e0} = 1200 nsec. We find that β decreases as pulse 2 fills more and more of the interval between pulse 1 and the echo.

We are interested in the effect of the driving field on the relaxation of the $^1S_0$ - $^3P_1$ optical coherence, but, as recently pointed out [9], the echo information is stored in the level populations as well as the coherence during pulse 2. As a result atoms experiencing strong collisions (and hence large random optical phase perturbations) may in principle still contribute to the echo signal through population-mediated information. It turns out, however, that the sign of this population contribution oscillates with the area of pulse 2 [9]. As a result, in our experiment, where the area of pulse

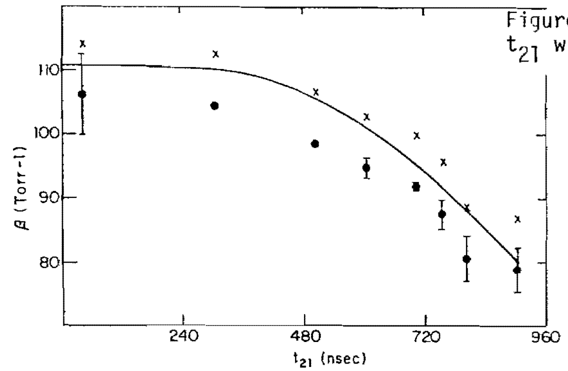

Figure 2. Echo decay constant β vs t_{21} with $t_e - t_o$ = 1200 nsec.

2 varies by ≈10π over the laser beam profile, the net population contribution from atoms having experienced large collisional phase-changes is expected to be very small, and the echo relaxation should very closely reflect the relaxation of the optical coherence.

The solid line in Fig. 2 was computed using known collisional decay parameters for this system [10], and assuming that the driving field completely suspends intercollisional velocity-change mediated phase relaxation, but leaves intracollisional optical phase randomization unaffected. The excellent agreement between our corrected data (X) and calculation support these assumptions.

Our results, characteristic of a completely different relaxation process than that found in solids, should provide an interesting test for theoretical treatments of relaxation in the presence of a strong driving field.

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